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MOBILE ROBOT NAVIGATION IN KNOWN MANUFACTURING PLANT ENVIRONMENT USING PARTICLE SWARM OPTIMIZATION

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Abstract

In the present era, most of the manufacturing industries are inclined towards the implementation of robotics technology for productivity enhancement. Autonomous guided vehicles have been used widely in manufacturing plants for material transportation from one location to another without involvement of human intervention. However, the localization and path planning is a challenging task in the field autonomous mobile navigation. In order to overcome this difficulty, the current study deals with the development of path planner using particle swarm optimization. With the developed path planner, the mobile robot can navigate in known environment of manufacturing plant efficiently. Simulation results are provided to validate the proposed methodology in various environments of known manufacturing plants.

Keywords: *Path planning; autonomous guided vehicle; particle swarm optimization; known environment; manufacturing plant*.

1. Introduction

Material transportation is an important task in any industrial process while producing the desired outcomes. An efficient material transportation system not only increases the productivity but also reduces the product cost. In recent days, mobile robots have been widely used for material transportation in manufacturing plants [1].

Mobile robot technology has been implemented for known and unknown environments under several assumptions in the past [2-5]. Wide range of artificial intelligence techniques have been addressed towards the development of an efficient path planner in known environments. Hassani et al [6] introduced frees segments and turning points algorithm for navigating the mobile for efficient obstacle avoidance. Zhang et al. [7] addressed wheedled mobile robot path planning in uneven terrains with partial known environment. Mohanta and Keshari [8] implemented Fuzzy inference system for mobile robot motion while creating number of rules correlating robotic actions and environmental situations. Apart from these, there are other artificial intelligence techniques namely potential fields method [9], reinforcement learning [10], Particle swarm optimization [11], and ant colony optimization [12] etc. have been applied for solving mobile motion planning problem.

The current research work deals with the development of an efficient motion planning strategy in the known manufacturing plant environments using Particle Swarm Optimization (PSO). The reaming of this paper is organized as follows: Section-2 describes the typical layout manufacturing plant of possible robot navigation. Section-3 addresses the basic model of PSO.

Section-4 deals with the development of fitness function for the implementation of PSO to solve mobile robot navigation. Section-5 discusses the results obtained after implementation of the developed algorithm in various environmental scenarios. Finally, Section-6 concludes the summary of the paper work along with the future scope of study.

2. Manufacturing Plant Layout

A typical manufacturing plant consists of number of manufacturing cells where some manufacturing process like machining, fabrication or assembly takes place. Let us consider there are 'n' numbers of manufacturing cells in the plant as shown in figure 1.

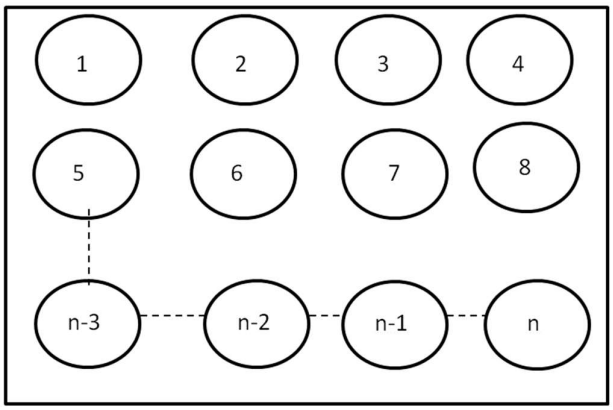

Fig. 1: Arrangement of manufacturing cells

Semi-finished or finished parts are to be transported from one cell to another through the pre-defined path as represented in the Figure.2.

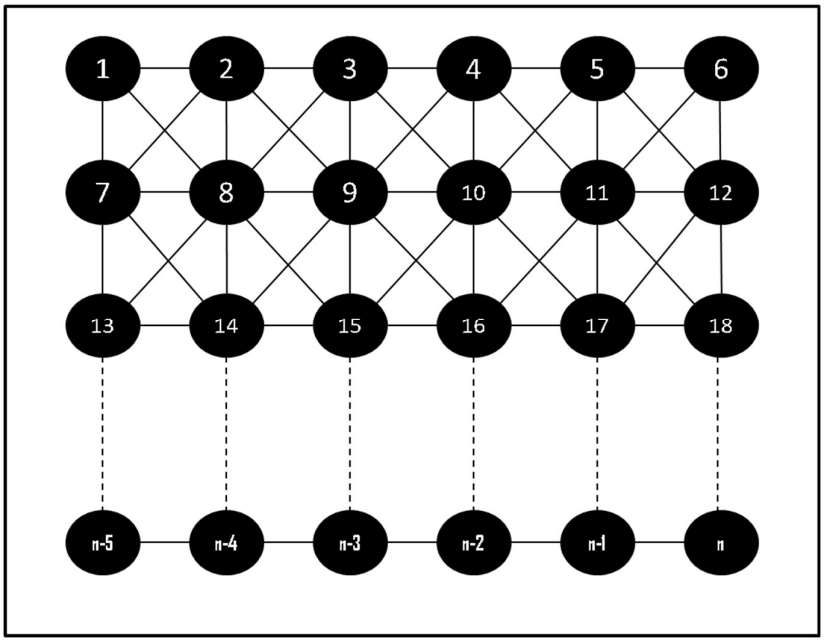

Fig.2 Pre-defined paths among the cells in the manufacturing plant

Now, an industrial engineer can provide the sequence of the target positions or the cells where the parts to be moved in the environment for the necessary manufacturing process.

3. Basic Particle Swarm Optimization

PSO is a swarm based strategy to be implemented for solving engineering problems. PSO is an evolutionary algorithm which is inspired from fish schooling or bird flocking nature. The number of birds or a group is flocking to reach the food destination, each individual communicates with others for deciding next best position to be moved.

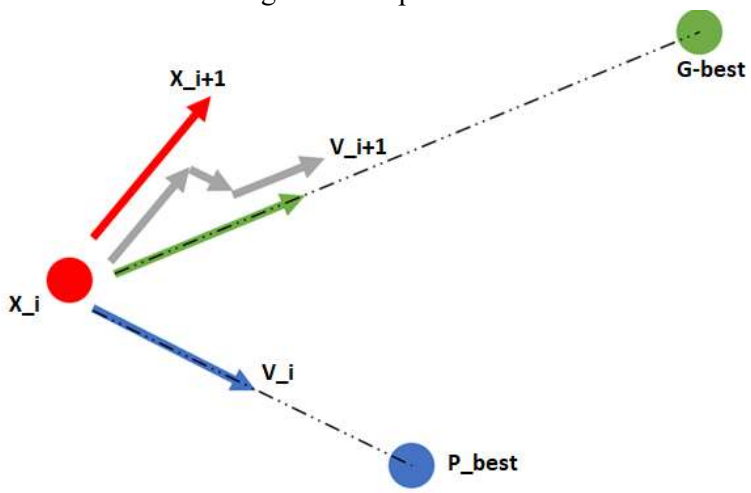

Figure.1 Architecture of PSO

Initially, the bird at its present position and velocity i.e. x_i and v_i. Now the particle tends to move its best position P best as shown in the figure.1. the same way all the particles in the swarm tend to move to their best positions. However, after communicating all the best position of each individual, they finalise one global best position. Thereby, each individual update its velocity to v_i+1 to reach the G best position as represented in Figure.1

4. Fitness Function Generation

The objective of the study is to optimize the path travelled by the robot within its known environment. Hence, a fitness function is to be assigned in terms of distance between robot and next assigned target position / cell position in the plant.

Let us consider,

Robot position = (R_x, R_y)

Target position = (T_x, T_y)

F = distance between robot and next assigned target position (d_{rti})

$$d_{rti} = \sqrt{(R_x - T_x)^2 + (R_y - T_y)^2}$$

The aim of algorithm is to minimize the d_{rti}.

Where d_{rti} represents distance between robot and i^{th} target position. There may be number of manufacturing cells in the manufacturing plant.

Assume the sequence of manufacturing cells is 1-6-7-…n. So the robot has to move in the described path while minimizing the values of d_{rti}.

To reach the first manufacturing cell the fitness function: d_{rt1}

To reach the second manufacturing cell the fitness function: $d_{rt\_1t\_6}$

To reach the third manufacturing cell the fitness function: $d_{rt\_6t\_7}$

To reach the n^{th} manufacturing cell the fitness function: $d_{rt\_n\text{-}1t\_n}$

5. Results and Discussion

The proposed PSO based motion planning strategy is implemented to various industrial environments. The following assumptions are made for PSO implementation:

- Population size: number of manufacturing cells.
- All the random values in the algorithm are set at '1'.
- Robot has prior knowledge about the location of all manufacturing in the plant.
- Robot is travelling with uniform speed while reaching the target positions.

Case-1: A single Manufacturing Cell

For easy understanding, the study starts with robot navigation in manufacturing plant with single cell as represented in Fig.2.

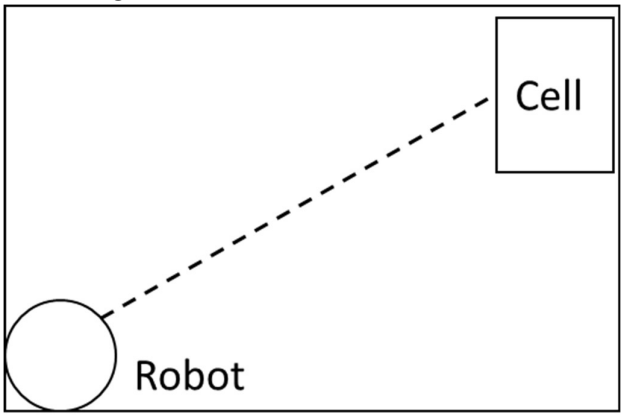

Fig.2 Environment with single cell

In this scenario, the robot directly measures the displacement from the cell location and navigates along the shortest path to reach the manufacturing cell.

Case-2: Multiple Manufacturing Cells arranged sequentially

In this scenario, the plant is considered with five manufacturing cells. The robot is started its movement to reach its target positions sequentially T_1- T_2- T_3- T_4- T_5 as represented in Fig.3. The shortest path of the robot to reach each target is represented in various colours in the simulation environment.

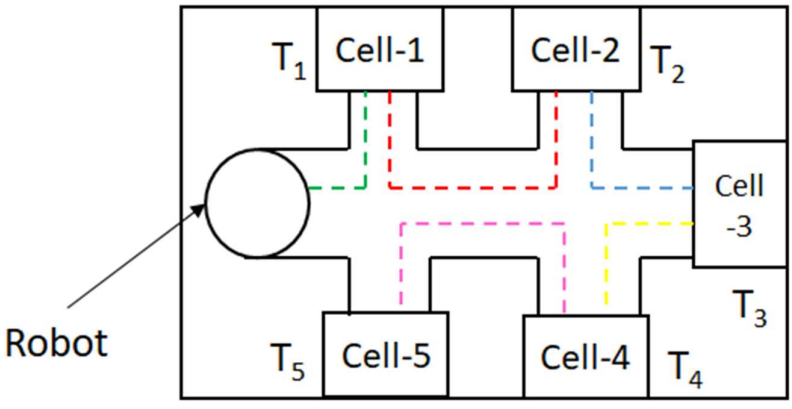

Fig.3 Multiple manufacturing cells Sequence target position

Case-3: Multiple Manufacturing Cells random arrangements

The same layout of manufacturing plant of case-2 is considered in this scenario. However, the arrangement of target positions assigned by the industrial engineer is not in sequential with respect to cell positions. Initially the robot is reached to first target i.e. Cell-1 then it started its movement to Cell-4 which is second target followed with the movement to Cell-2, Cell-3 and Cell-5 as represented in Fig.4.

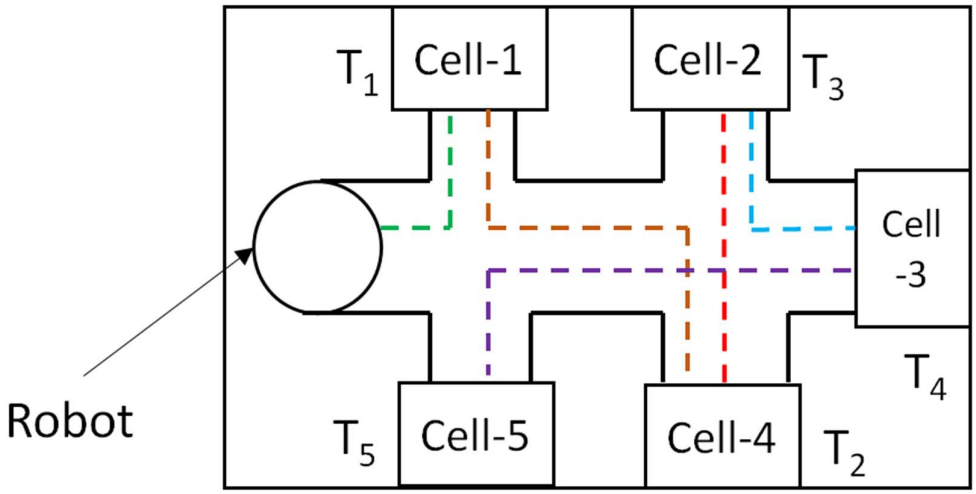

Fig.4 Random target position in the plant

Table .1 depicts the path analyses results for the considered cases.

Table.1 Path Analysis results

Environment	Path Travelled (mm)	Time taken (sec.)
Case-1	1050	230
Case-2	4500	987
Case-3	6800	1490

6. Conclusion

In this paper, mobile robot navigation problem for known environment has been solved. The robot navigation is achieved with the implementation of artificial intelligence technique known as particle swarm optimization. The swarm intelligence is applied to reach the target position in the predefined manufacturing plant. Several case studies representing typical manufacturing environments have been considered in order to validate the proposed methodology. As a future work, the proposed technique is to be implemented in real time environments.

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